THE DIAMOND-DEPOSITS OF COPETON, NEW SOUTH WALES.

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(Plates xc.-xcii.)

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i. Introduction.

The Copeton diamond-field has its centre of activity at Copeton, a small township on Cope's Creek, about two miles above its junction with the Gwydir River. It is thus on the western edge of the New England tableland. The present paper is the result of observations made during June, 1909, May, 1910, and January, 1913. A number of investigators had previously given some attention to the field, and several papers have been published in connection with it. The earliest report which I have been able to trace, is that of Mr. C. S. Wilkinson(10) to the Surveyor-General, in July, 1873. In this report, he refers to the operations of the Borah Tin and Diamond Mining Company on the alluvial drift, which, he suggests, has been derived from the denudation of the deep leads. It is now known that this suggestion is the correct one. Other reports have been furnished from time to time by officers of the Department of Mines, the chief of these being that of W. Anderson(2) in 1887. This communication was accompanied by a geological map of the district in the neighbourhood of Copeton. This map, somewhat modified and added to, has been incorporated in this paper. Another report of some value is that by G. A. Stonier(8) in 1894. An excellent summary of the work accomplished, up to the date of publication, was given by Mr. Pittman(7) in his book, "The Mineral Resources of New South Wales," which appeared in 1901. The most interesting fact, from the scientific standpoint, was the discovery of a diamond in its true matrix by Messrs. Pike and O'Donnel in 1904. An account of this was published in the Annual Report of the Department of Mines for that year.

More recent contributions to the literature of the subject have been made by Professor David(4), Mr. J. A. Thompson(9), and Mr. A. R. Pike(6).

ii. The Nature of the Leads.

The diamond-bearing drifts fringe the depression which lies between Cope's Creek and the Gwydir River. (See Plate xci., fig. 2). As the first diamonds discovered were won from *recent alluvials*, these will be first described.

Reference has already been made to the fact that diamonds were first found by miners in search of alluvial tin. In all these cases, these gems had been redistributed from Tertiary river-gravels. By this process, small quantities of these gravels were added to relatively large masses of recent river-gravels. In consequence of this, it is at once apparent that the diamonds must be scattered through a much greater amount of barren river-gravel than was the case in the old leads. In exceptional cases, where the denudation of the Tertiary gravels was rapidly effected, the recent alluvial deposits have proved payable. Koh-i-noor deposit and the old football-ground at Copeton are examples of this type of occurrence. The former place lies between two well defined portions of the Tertiary lead. The diamonds are here found distributed through a mass of basalt-boulders, which have been worn down from the neighbouring hills. These boulders have become encrusted and cemented by calcite, resulting from the decomposition of the basalt itself. At the latter place, the diamonds have been derived from the destruction of a tributary of the main lead, which connected Soldier Hill with the Round Mount.

Though a few diamonds have been won from these recent deposits, by far the greater number have been recovered from the Tertiary deposits. In rare cases, the basalt-capping has been denuded, and the gravels lie exposed at the surface. These original deposits are readily detected from the recent alluvials, both by their position and the nature of their gravels. Examples of such deposits are the Streak of Luck, and the Sandy Block. The greater part of the Tertiary gravels, however, are now to be found underlying basalt-flows at various depths from the surface.

The age of the diamond-bearing gravels can be determined only relatively to the rocks between which they lie, as no definite internal evidence has yet been found. Though lignite occurs in several of the mines, no definite plant-remains have been obtained from this locality.

The granites are to be correlated with those at Ashford, which have been stated to intrude Permo-Carboniferous sediments. The coarse grain of the granite indicates that it must have consolidated under a considerable thickness of the sedimentary rock. As, however, but little of the latter remained at the time when the basalt-flows occurred, a considerable interval must have elapsed between the intrusion of the granite and the formation of the deep leads.

The evidence of fossil leaves, from other leads in New England, points to a late Tertiary age for the basalts of the plateau. In the lack of any more definite evidence, therefore, the Copeton diamond-deposits may be regarded as of late Tertiary age.

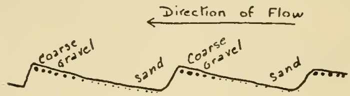
Tertiary gravels.—The nature of the diamond-bearing drifts has obviously been determined by the character of the country over which the prebasaltic streams flowed. The main lead at Copeton has had its course entirely in granite. This rock is of an aplitic character, and, being composed chiefly of quartz and felspar, has, as its products of decomposition, quartz-grains and kaolin. The latter product, on account of the ease with which it is carried in suspension by running water, can be deposited only where the water is comparatively still, as in lagoons. Conversely, the occurrence of any kaolin-deposits implies comparatively still-water conditions of deposition.

A few small tributaries of the main lead have intersected the sedimentary rocks (chiefly clay-slates), and have thus locally introduced a third factor.

As the processes of river-development do not vary with geological time, the Tertiary leads exhibit features in common with present-day streams. Large boulders, for example, occupy a great portion of the old river-channels. These are often so large as to be mistaken for portions of the walls or bottom of the river-channel, and are a source of continual trouble and perplexity to miners. In general, of course, there is an arrangement of the coarsest material at the base of the drift, and a diminishing coarseness of texture with distance from the channel-bed. This type-arrangement is subject to modification in which a number of coarse bands mark the temporary level of the stream.

The drifts are almost invariably of a reddish colour, which is due to the staining effect of the iron-oxides leached from the overlying basalts. The thickness of the drifts varies very greatly, even at short distances. This may be attributed to two causes, the first being the irregularity of the bed of the stream, and the second, the differences in grade; a swiftly flowing current, on a steep grade, tends to sweep the channel-bed free from all loose material.

The greatest thickness of drift observed at Copeton was at the Round Mount. Here a depth of 25 feet was encountered. The "wash," as it is called, differs from the main bulk of the gravel in being coarser in texture and more compact. At the Round Mount, the bulk of the gravels consists of small quartz-grains from 2 to 5 mm. in diameter. The wash, on the other hand, consists chiefly of quartz-pebbles from 5 mm. to 3 cm. in length. The pebbles are of the normal stream-type, being ellipsoidal in form. The slightly predominant tendency of these pebbles to lie with their long axes sloping upwards towards the south-east, indicates that the flow was probably in that direction. Amongst the quartz-pebbles in the wash are to be found a number of blue-coloured rocks, subangular or ellipsoidal in form, and ranging from 2 to 24 cm. in length. This particular band of rock is 20 cm. in thickness, and lies between gravel and drift of normal character. The existence of these bands of wash, at different levels in the drift, is doubtless due to the action of minor floods. Andrews has shown that the work of aggradation is performed in the interflood period. Each moderate flood excavates some of the material aggraded during the interflood period. The largest, or true flood, removes the whole of this material, and corrades the channel. As the flood subsides, aggradation commences; matter held in suspension gradually settles; the coarser material, on account of its greater weight per unit of surface, sinks first, and thus a grade from coarse to fine material is established. Pebbles of greater density associate with larger stones of less density; and, finally, sand covers the whole. The effect of a moderate flood, on the deposit, following a large flood, will now be considered. The moderate flood has not sufficient energy to remove the whole of the material deposited after the large flood, but it can remove some of it. As this moderate flood begins to subside, deposition takes place, and another series is formed having the coarser pebbles at its base. Thus it is possible for many zones to be formed. The coarser pebble-zones formed in this way constitute the layers of wash. The lowest layer of wash is usually the most payable, as the diamonds are larger and more abundant. The layers of wash are somewhat irregular. The bottom-layer follows the contours of the channel-base, which is generally very uneven. The upper layers of wash, on the other hand, conform very uniformly to the horizontal, as they are built up on the loose sands and gravels, which readily adjust themselves to the level under the influence of running water. Yet there is a degree of irregularity : the wash seems to be cut off very abruptly in places, and no clue seems to be afforded by which it may be traced. A very striking illustration, which may explain this irregularity, was observed in the bed of Cope's Creek, near its junction with the Gwydir. A recent flood of considerable strength had passed along the channel of the stream, but, at the time of observation, only a small stream was running. The notable feature was the arrangement of the sands and gravels in the creek-bed. These were deposited in wedge-shaped blocks, having the thin edge of the wedge pointing up-stream. A diagrammatic section of these deposits along the length of the stream is given in Text-fig.1. This would seem to correspond to Andrews' step-like structure in the evolution of stream-development. The slopes were from 20 to 30 feet in length, and the steps from 2 to 3 feet in height. The depressions caused by these steps were of the shape of isosceles triangles (Plate xci., fig.2), having the apex of each triangle pointing down-stream, and the base perpendicular to the direction of flow. The length of the base varied from 6 to 10 feet, and the height of the triangles from 8 to 10 feet. The depressions were in sand having a grain-size from 1 to 3 mm. The upward-sloping surfaces of the gravels were covered, to a depth of about 2 inches, with coarse pebbles, from 3 to 7 cm. in diameter. If these were buried under a further load of drift and sand, and then covered by a basalt-flow, they would present the same discontinuity, in the beds of wash, as are met with in the deep leads. The study of such features should be of value in the prospecting of deep leads.



Text-fig. 1.—Section of bed of Cope's Creek, parallel to the stream.

In a deep lead, there are four well marked zones in the materials deposited, any or all of which may be present. These are—

(1). The coarse gravels known as the wash.

(2). The medium-grained sands and gravels constituting the main bulk of the deposits.

(3). A deposit of fine mud or clay.

(4). A deposit of vegetable-débris, which has, not infrequently, been converted into lignite.

Of these, the wash has been partly discussed in relation to its occurrence at the Round Mount. It has already been noted that the leads under consideration are entrenched in granite, save where a few tributaries have intersected the slate-formation.

It is to be expected, therefore, that the gravels and sands would consist of simple products, and, with regard to the great bulk of them, this is true. There are, however, to be found, intersecting the granite, a great number of small reefs containing many different minerals. It is from these reefs that the bulk of the wash is made. The hard parts of the wash comprise quartz, tourmaline, topaz, jasper, zircon, cassiterite, garnet, and diamond. The soft parts are made up of kaolin, decomposed granite-pebbles, and decomposed pebbles of basic igneous rock.

In the main lead, the wash is fairly coarse, the average size of the pebbles ranging from 1 to 8 cm. in diameter. Occasional boulders are met with, from this size up to several feet in diameter.

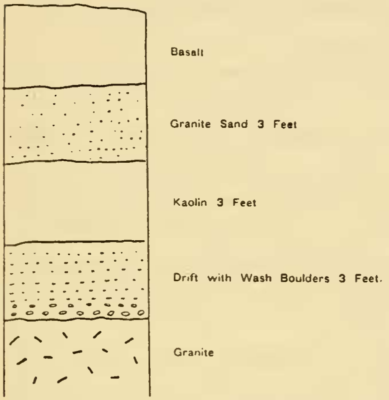
A large percentage of the hard wash-pebbles are quartz, probably more than 90 %; and these can have been derived only from the reefs in the granite. Tourmaline-pebbles are next in order of abundance. These are not of large size, being, as a rule, rather less than 1 cm. in length. They are generally more bean-shaped than the quartz-pebbles, this, no doubt, being due to their formation from the "pencil-tourmaline" so common in the quartz-reefs. The proportion of tourmaline to quartz-pebbles varies greatly from place to place, but rarely exceeds 5 %. The topaz, which occurs in the wash, has, no doubt, been derived from the same source as the tourmaline, but the amount present is very small, and is only noticeable when concentration has been effected. A similar statement also applies to the garnet found in the leads. These gems are small, rarely exceeding 4 mm. in diameter. It is this mineral more than any other which is constant in its association with the diamond. Sapphire is only occasionally met with in association with the Copeton diamonds, and zircon is a rare associate, but special characteristics distinguish the wash from different parts of the lead. The thickness, the degree of coarseness, and the relative amounts of the various constituents, are all very variable quantities. At Soldier Hill, a number of sharp, angular quartzes are present in the wash, so that, doubtless, a reef is close to this deposit. Here, also, a number of jasper-pebbles occur. These are grey stones, much flattened and waterworn. It is evident that they have travelled a considerable distance, having probably been derived from jasperoid bands in the slate-formation. At Benson's farm, better known, perhaps, as the Old Farm, the wash is unusually coarse, boulders up to 20 cm. in diameter being very common.

In some places, the wash has undergone secondary change, as at Kirk's Hill, and the Banca mines. Here, a very common feature is what is locally known as the iron-band. This is a layer of wash which has been cemented by the infiltration of iron-bearing waters. It so happened that the wash, thus altered, was rich in diamonds, and a considerable quantity of it has been profitably mined. It was found that the band was too hard to be crushed without risk of fracturing the diamonds. This difficulty was overcome by heating the material on iron.plates, care being taken not to raise the temperature to the combustion-point of the diamond. The differential expansion of the diamond and its host caused the stones to become freed by this method.

The second zone of the deep lead deposits—*the drift*—constitutes by far the greatest bulk of the material. The sands comprising this possess a grain-size of about 2 to 3 mm., and frequently enclose one or more subsidiary layers of wash. The maximum thickness observed was about 35 feet at the Round Mount. Some of the grains are waterworn, while others are angular, but there is nothing very distinctive about the main mass of the material. It is not found to contain diamonds in payable quantities, even where the gems are most abundant, though occasional stones have been recovered from it.

The third zone—comprising fine mud and clay—occurs only at a few places on this field. At Rider's lead, the most noticeable feature is the presence of a large body of pipeclay, which overlies the gravels of the diamond-bearing wash. This portion of the lead has been worked for nearly a mile, and the bed of pipeclay has been found practically continuous throughout that distance. The clay is a soft, white material, almost pure kaolin, and has an average thickness of about 2 feet. Below it, lies the drift, and below this, again, is a bed of wash, from a few inches up to a foot in thickness. The whole series is covered by a considerable thickness of alluvium, in some places as much as 50 feet in depth. The lead runs from south to north, and only the latter end is covered by basalt.

Again, between the Star of the South Mine and Davis' block, a section of the lead is to be seen, where it has been exposed by mining operations. In this case, a rather unusual arrangement occurs (See Text-fig.2). The pipeclay-band, which is 3 feet in thickness, is overlaid by a fine granite-sand, and rests on gravels, the pebbles of which have a diameter of about 4 mm. This deposit lies at the junction of the two main streams of the Tertiary lead, and is capped by basalt.



Text-fig.2.—Section of the Tertiary Lead between the Star of the South Mine and Davis' Block.

The fourth zone mentioned—that comprising vegetable-débris—is of relatively rare occurrence on this field. The most typical example is that of the Crown Jewel Mine. Here, the vegetation, which has been converted into lignite, overlies the drifts, and is of considerable extent. A tunnel was driven through the drifts for more than 100 feet, and the roof of this drive was in lignite for the whole distance.

iii. Physiography.

In an investigation of the kind embodied in this paper, the two phases which are of most physiographic interest are evolutionary ones. The problems presented are—How has the present topography been developed; and what is its relation to the pre-Tertiary condition? Several elements have contributed to the process, and the chief of these are as follow: (1) denudation, (2) earth-movements, and (3) volcanic phenomena.

If it were possible to replace, in its original position, the mass of material removed by the agency of denudation since the basaltic period; to remove the basalts entirely; simultaneously to readjust, in their proper chronological order, the results due to earth-movements; there would then appear, in its original state, the topography of the pre-basaltic period.

Mr. E. C. Andrews has given an excellent general account of the physiography of northern New England. He has shown certain stages of peneplanation, the youngest of which has left its record as the Stannifer peneplain; and the physiography of Copeton is dominated by this feature.

A study of the contours on the accompanying geological map reveals three topographical units. These are :—

(1). A relatively low-level area bounded, on its north and east sides, by the Gwydir River. This is about 2,200 feet in height.

(2). An area of moderate relief situated north of Cope's Creek and the Gwydir. This area has an altitude of about 2,800 feet.

(3). An area of relatively high relief situated to the east of the Gwydir, and to the south of Cope's Creek. This area attains an altitude of as much as 3,400 feet.

The first of these is wholly in the Oakey Creek granite-area. I examined about one hundred square miles of this area, but failed to obtain any evidence that it had been covered by basalt. If such has been the case, denudation has removed all trace of the lavas. The channel of the Gwydir is about 200 feet below the general level of this area.

The second unit presents more variety in its geological structure. The basal rock is granite. Two types—the Oakey Creek granite and the Acid granite—are present, and these are separated approximately by a tributary of Cope's Creek (see Plate xcii.). There are also masses of clay-slate included in the area, mainly to the east of the Auburn Vale Creek. Basalt overlies a considerable portion of each of these rocks. This area represents the denuded surface of the Stannifer peneplain.

The third unit is composed of the Acid and Tingha granites, and basalt has been found only along old valleys cut in these structures. This area also represents part of the original Stannifer peneplain. Further data are yet required for the solution of the problem. These are supplied by a knowledge of the positions and directions of flow of the Tertiary streams. These may be seen by a reference to the accompanying geological map, on which they are represented by thick black lines.

As a preliminary step towards solving the problems connected with the pre-Tertiary stream-development, it will be well to consider the present rivers and their origins. The chief of these are the Gwydir River, and its tributary, Cope's Creek. The question arises, has the course of the Gwydir been determined by the re-opening of some Tertiary stream, or has it had its direction controlled by some large structural feature developed subsequently to the basalt-period?

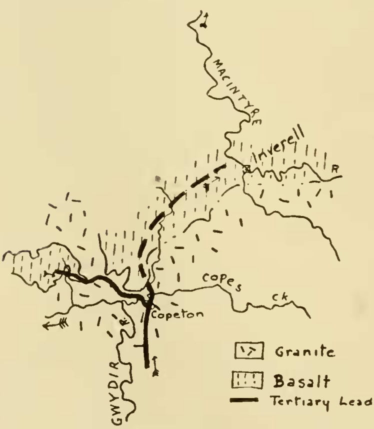
The accompanying map shows that a pre-basaltic stream flowed from Oakey Creek to Copeton, in a direction approximately parallel to the Gwydir, but in a contrary direction. Moreover, the distance between the two streams is less than two miles, while the difference in their levels is about 100 feet. The great instability of such a system is opposed to the existence of the Gwydir as a pre-basaltic stream. Again, it would be strange indeed if the basalts, which covered the Oakey Creek lead with a thickness of several hundreds of feet of basalt, had not filled the valley of the lower adjoining river. The fact that no trace of basalt has been found on the low-lying area to the south-west of the map, is also opposed to this view. It may be concluded, therefore, that the present Gwydir has been developed in a direction quite independent of the pre-basaltic drainage-system.

If the present course of the Gwydir be regarded as post-basaltic, its position must be due either to haphazard denudation, or to some definite structural feature. The presence of the relatively low-lying block, bordered on its north and east sides by the Gwydir, is the factor which serves to discriminate between these two explanations. It is highly improbable that the processes of denudation can have exerted such a selective influence on the low area lying to the south and west of the Gwydir, while steep escarpments rise abruptly from the other side of the river. The assumption of a faulted block, on the other hand, accounts both for the low level of the area discussed above, and also for the marked change of direction of the Gwydir at its junction with

Cope's Creek. This explanation, moreover, implies that, at the period of basaltic intrusion, this block-faulted area was at a much higher elevation, and, consequently, more likely to have escaped being flooded with lava; and it has been pointed out that no evidence of basalt was found on this area.

It thus appears probable that the Gwydir is a post-basaltic stream, which has followed the direction of the two faults bounding the north-east corner of a fault-block.*

The reconstruction of the pre-basaltic physiography, then, involves the elevation of the fault-block into its original position. If we suppose this to be done, there remains only the removal of the basalts to restore the conditions of the pre-basaltic physiography. The presence of river-gravels, and of V-shaped sections of basalt lying on granite-foundations, enables a large amount of this imaginary construction to be readily performed.



Text-fig.2*a* --Map showing the Tertiary and Recent river-systems of the Gwydir and Macintyre near Inverell.

The final result of this readjustment of the effects of natural processes transforms the area into a denuded peneplain at an elevation of 3,000 feet above sea-level. The discussion on the disposition of the Tertiary leads indicates that the pre-Tertiary streams united to form a north-flowing river. This tendency of the pre-basaltic drainage to flow north is in marked contrast to the present trend, which is towards the west.

From the junction of Auburn Vale Creek with Cope's Creek, a broad basalt-flow trends northwards towards the western side of the town of Inverell. For about half the distance, the flow is limited on each side by granite; but, near Inverell, only the eastern boundary is

* Further evidence of faulting occurs to the west at Keera Station.

well marked. The level of the basalt on the western side is above the peneplain-surface of the granite-area. This flow undoubtedly represents a pre-basaltic valley, which was completely obliterated by the lava-flows. Subsequent denudation has exposed the granite along the eastern side, and partly on the western side. (See Text-fig.2*a*).

As the pre-basaltic Gwydir has been traced directly into the southern, truncated end of this flow, there can be no doubt that the Gwydir originally continued in this direction.

Moreover, it is clear that the Macintyre at Inverell has been redeveloped along the course of a pre-Tertiary stream from Newstead to Inverell. Thus it would appear that the Macintyre-Gwydir originally formed one stream-system, which has been severed by the large basalt-flow extending from Copeton to Inverell.

iv. The Distribution of the Diamond-leads.

The subject-matter of this Section will be rendered clear by reference to the accompanying geological map(Plate xcii.). This map is practically that of Mr. Anderson, published in 1887. A few additions and alterations, including the contours, have been made by the author. Previous workers have held the opinion that the main Tertiary stream flowed west from Copeton to Bingara. It has been stated, in support of this hypothesis, that the size of the diamonds found in the river-gravels decreases from Copeton towards Bingara. It has been argued that the largest diamonds would remain nearest their source of origin, and the smallest would be carried farthest down stream. This argument is, no doubt, correct, but the converse is not, in this case, true. The observation of numerous aneroid readings, which were checked and standardised, has shown that the Tertiary lead on the north side of the Gwydir has not flowed towards Bingara, but in the opposite direction. Some other reason must, then, be assigned to account for the fact that the diamonds are larger at Copeton than at Bingara.

The levels observed are recorded on the sketch contour-map. The gaps between the remnants of the basalt-leads have been examined, and the Tertiary stream-channel reconstructed as shown. A short description of the various places, where diamonds have been found, will serve to connect these, and to illustrate their relationships.

The most southern claim is that known as Rider's Lead. This lead heads on the present divide, between Maid's Creek and Sandy Creek, at an elevation of about 2,600 feet above sea-level. This is near the junction of the Acid with the Tingha granite, but the lead itself lies chiefly within the Acid granite-area. Very little basalt is now present, and the greater portion of the lead is now concealed by alluvial deposits at a depth of about 50 feet. The characteristic feature of this occurrence is the zone of pipeclay, which overlies the drift and wash. Owing to the neglected state of the workings, I was not able to investigate underground; but, from information supplied by Mr. Skippen, it would appear that the body of wash was not more than a few inches in thickness. This was overlaid by about three feet of rather coarse drift (containing pebbles up to 1 cm. in diameter), and the whole covered by two or three feet of pipeclay. The basalt-capped part lies three-quarters of a mile below the head of the lead. It is probable that, when this lower portion was overwhelmed by basalt, a lake was formed in which the fine kaolin from the decomposition of the felspars was deposited. There is no evidence that the head of the lead was ever covered by basalt. Little success has attended the exploitation of the deposits underlying the basalt, most of the diamonds having been won from that part underlying the alluvial deposits.

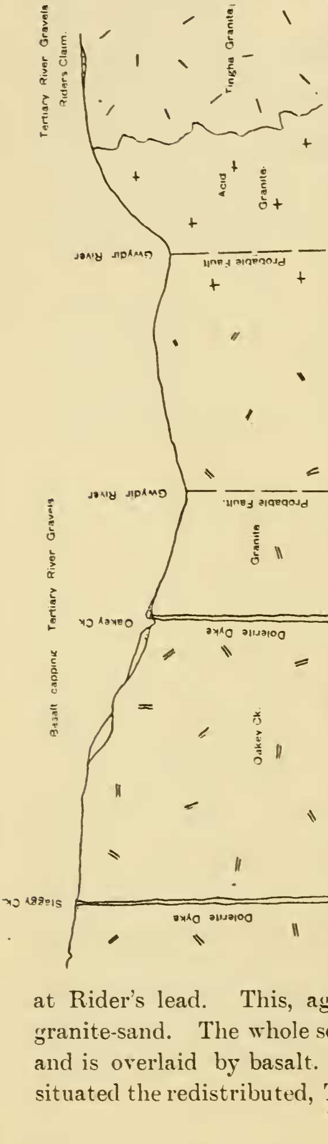
The minerals associated with the diamond in this lead are tourmaline, topaz, tinstone, jasper, and garnet. The diamonds, as usual, were recovered from the wash, in which they were irregularly distributed. Several good finds were made in small potholes. The stones were of better size and quality than the average production of the Copeton field, and numbered about three to the carat. Bort is also recorded from this locality.

Following the lead north, the next place where diamonds have been found is at Kenzie's claim. Here the lead has been almost entirely swept away by the present creek, but a small area of basalt, considerably less than an acre in extent, still remains. The discovery of diamonds here is only of importance, for the purpose of this paper, as a piece of evidence as to the course of the lead.

At Collas' Hill, diamond-bearing drifts have been worked with some success. Here, the basalt has been intersected by the present stream-course, and has exposed the Tertiary gravels on the side of a hill. These deposits were prospected by means of tunnels, driven at the level of the wash, which stands at an elevation of about 2,280 feet. The diamonds found here averaged about four to a carat, and contained a number of triangular, flattened crystals.

The Streak of Luck Mine is situated on the next remnant of the Tertiary lead. Here the basalt has been entirely denuded, and the gravels lie either exposed at the surface, or buried under a few feet of alluvial. The level of the wash at this mine is about 2,250 feet. The diamonds from this locality averaged about four to the carat.

The Deep Shaft Mine adjoins the lease just mentioned. The diamond-bearing drifts are here covered by basalt, varying in thickness from 50 to 130 feet. This has been one of the most productive mines on the field. A small tributary from the south-east joined the lead at this point. This has introduced, into the lead, boulders of clay-slate from a small area of this rock about half a mile distant. In places, these boulders are several feet in diameter, and overlie the sandy drift. The wash is normally about one foot in thickness, and is covered by sandy drift, the grainsize of which is from 3 to 6 mm. The diamonds occur in the wash, and are associated with quartz, topaz, tourmaline, garnet, sapphire, zircon, and tinstone. The gems are found unevenly distributed, often occurring in clusters where concentration has taken place. It is recorded that 150 carats have been recovered from a single load of wash-dirt. It is noteworthy, that the diamonds won from this mine are larger than those from the lead above this place. The stones average three to the carat, and are of good quality. From 40 to 50 per cent. of the stones are white, rather more are a light yellow, while a few are brown and green. Well developed octahedral crystals are conspicuous; probably 6 to 8 per cent. of the diamonds being of this nature.



Text-fig. 3.—Section from Staggy Creek to Rider's Lead, showing the relations of igneous rocks and faults.

A number of the crystals exhibit twinning. Pieces of bort, several carats in weight, have also been found at this mine.

The lead next passes through Davis' block. Here it is also concealed by basalt, though the depth of the wash from the surface is lessened by the fact, that a small stream has removed a considerable portion of the basalt-capping. The lead, at this point, swings round from a north-east and takes a north-west course.

At the Koh-i-noor Mine, which is situated about 150 yards beyond the last-mentioned block, the basalt has been removed from the lead on its western side. A section of the deposits (see Text-fig 3) shows that the bedrock is a very decomposed granite. Upon this rests a body of gravel, some three feet in thickness. There is no prominent band of wash in this, but the whole consists of small quartz-grains and pebbles about 4 mm. in diameter, which have been derived from the decomposition of the granite. Above this lie three feet of pipeclay of the same nature as that noticed at Rider's lead. This, again, is covered by three feet of fine granite-sand. The whole section has been exposed by tunnelling, and is overlaid by basalt. Immediately to the west of this is situated the redistributed, Tertiary gravels previously mentioned.

The Star of the South has been more productive than any other mine on this field. The bulk of the material mined was hauled from Skippen's shaft, which is 90 feet in depth. The shaft was sunk through basalt until the underlying granite was encountered. The sinking was then continued into the granite, and two drives put in to intersect the wash, and so drain the lead. Both drives intersected a dyke nearly at right angles. In one drive, the dyke attained a thickness of one foot, and in the other it was six inches. The dyke-material was decomposed to a yellow clay. Boulders of this clay were found in the diamond-bearing wash in association with the gemstones.

Adjoining the Star of the South Mine, is Benson's block, better known as the Old Farm. The lead is here covered by 60 feet of basalt, and a considerable amount of water was present in the drift and gravels. The wash was of a very coarse nature, and contained a great number of quartz-boulders up to six inches in diameter. Boulders of granite were also abundant. The diamonds recovered from this mine were similar to those found in the Star of the South, and averaged from three to four to the carat. This mine is of special interest, as here the lead terminates abruptly at the northern end. This disappearance of the lead is explained by the fact that, at this point, the Tertiary stream-channel has been reopened by a recent watercourse, which has removed all traces of the diamond-bearing gravels. The recent stream has its channel on the floor of a steeply sloping gully, less than one quarter of a mile in length, and joins Cope's Creek at a very rugged spot. Beyond this, the lead must have crossed the present position of Cope's Creek. About half a mile to the north-west of this point, there is a large body of gravel and wash at an elevation some 20 feet lower than the gravels at the Old Farm. There can be no doubt that this was part of the main Tertiary stream-channel. The gravels have been prospected by means of tunnels, but no diamonds were found. A tributary flowed in at this spot from the south-west, and recent denudation has exposed, in several places, the gravels deposited along its course. These deposits have been exploited, but without success. The course of the main Tertiary stream has now been traced from Rider's lead, on the south, to a spot half a mile to the north-west of Cope's Creek on the north. Beyond this point, the Tertiary river-system is completely hidden by basalt-flows as far north as Inverell.

The western lead has not yet been considered. This was a large tributary stream, which flowed from a spot 10 miles west of Copeton, and joined the main stream at the town itself. The course of this lead is nearly parallel to that of the Gwydir, but the fall is in the opposite direction. The continuity of the lead has been destroyed by several creeks, which have worked back from the Gwydir. The effect of this is, that there now exist a number of isolated basalt-areas with a linear arrangement, yet separated by steeply flowing creeks. The extreme western limit of the lead, which has proved diamond-bearing, is at Oakey Creek. Here a north-flowing tributary of the Gwydir has intersected the east-flowing Tertiary lead, leaving the gravels exposed at the surface on each side of its valley. The deposits were worked by means of tunnels, and both diamonds and tinstone recovered from the wash. It was while driving a low-level tunnel in the granite underlying these deposits, that Messrs. Pike and O'Donnel met with a very remarkable occurrence. The tunnel was found to intersect a large body of decomposed igneous rock, and it was noticed that a great deal of this was found in the wash in association with that part of it which was richest in diamonds. The dyke-rock is a dolerite. It does not outcrop on the hill-slope, but is entirely covered by basalt.

The diamonds found at Oakey Creek are rather smaller than the average Copeton diamonds, ranging from four to five to the carat. About half the stones recovered are white, and most of the remainder straw-coloured. Few octahedra have been found, and there is no record of bort having been discovered.

The lead continues through the hill forming the watershed between Oakey Creek and Kirk's Creek, and the gravels again outcrop on the eastern slope of this hill. Here another drive, known as Dodd's tunnel, was put in to reach the wash near its bottom-level. This tunnel, like that at Oakey Creek, also intersected a dyke, boulders of which were in the adjacent diamond-bearing wash.

About half a mile further east is Kirk's Hill. This claim is renowned for having produced the richest find of diamond-bearing wash in the district. It is reported that, from four loads of wash-dirt, 1,100 carats of diamonds were recovered. A number of large boulders were present in the wash, and these seem to have acted as a series of ripples in concentrating the diamonds. The usual associates of the diamond, topaz, tourmaline, tinstone, garnet, and quartz were also found here. Another decomposed dyke also occurs in association with these deposits. The gravels overlie the dyke in part, and soft, yellow, decomposed boulders, derived from it, are present in the wash. The wash here is at an elevation of about feet. A notable characteristic of the wash at this mine is the presence of what is known as the "iron-band" This name is applied to a layer of wash cemented by iron oxide of a very hard and tough character.

Following the lead further east, the Banca Mine is reached. This lies on the eastern side of Kirk's Creek, and was one of the earliest worked mines. Here, again, a dyke was met in one of the tunnels. The "iron-band" was also found at this mine, where it reached a thickness of two feet, and rested on a granite-floor. Tinstone was found associated with the diamonds.

Beyond Kirk's Hill and on the western side of the Malacca Creek, is another isolated area of basalt covering Tertiary gravels. The Malacca Mine is responsible for the exploitation of these deposits. The basalt has here been denuded so that the lead outcrops on both the eastern and western sides of the hill. The lead lies at the southern extremity of a basalt-capped hill, which bears north and south : it still maintains its east and west trend, and so outcrops on both the east and west sides of the hill. It has, however, narrowly escaped entire destruction, for the gravels, lying on its southern bank, have been exposed in several places on the southern slope of the hill. The distribution of the gravels is still mere obscured by the fact that a tributary stream joined the main lead from the south-west at this point. The result of this configuration is, that the wash outcrops at different levels at various parts of the hill. This is all very confusing at first, and the failure of the prospectors to interpret these facts has made the mining of these deposits a very difficult matter. There is sufficient tinstone present in the wash to make it worth while to recover it, when mining for diamonds. The diamonds are small, ranging from four to five to the carat. Bort is only rarely found at this mine. Here, again, another dyke was met in driving a tunnel into the hill from the west side. The tunnel was driven in a direction about north-east, and two cross-cuts were put in to the north-west, at a distance of 100 feet apart. Both these cross-cuts intersected a dyke. In the more western one, the dyke attained a thickness of 8 feet, but, in the eastern one, the thickness was only 2 feet. It is evident, from the position of this dyke, that the diamonds of the Malacca Mine lie on the downstream side of it. Accompanying the diamonds in the wash were numerous, small, bluish-coloured boulders, from 2 to 3 inches in diameter, derived from this dyke.

To the east of this occurrence, the lead has been denuded by the Malacca Creek, which is a short, steep stream flowing south into the Gwydir. On the eastern side of this creek, the basalt is again to be found covering the Tertiary gravels. This part of the lead has not yielded diamonds in payable quantities, and no local name has yet been assigned to it. The deposit is here from 10 to 12 feet in thickness. A band of coarse wash, containing quartz-boulders up to 2 inches in diameter, occurs about 3 feet from the granite-floor. A few clay-boulders were also noted, and these must have been derived from some dyke in close proximity. About 100 yards to the north-west is another body of drift, some 20 feet higher than the drifts just described. This also contains a number of clay-boulders, and may have been a tributary stream.

To the south-east of the deposit just described, is situated the outcrop of gravels known as Soldier Hill. This was one of the earliest mines worked for diamonds. The discovery of the gems was first made among the sand-grains on a soldier-ants' nest, and hence the name of the mine. The lead here turns to the south, and, beyond the south end of Soldier Hill, has been entirely denuded. Both diamonds and tinstone have been recovered from the wash. The stones recovered average from 3 to 4 to the carat. In this mine, besides the wash on the granite-floor, a top seam was also found to be diamond-bearing. A little free gold has been found in this deposit.

The bottom layer of wash is made up of granite-boulders, from 2 to 4 inches in diameter. These range from subangular to perfectly waterworn, ellipsoidal stones. This band also contains quartz and tourmaline pebbles, and is about one foot in thickness. About one foot above this band, are a number of waterworn pebbles, decomposed to a soft bluish clay. These are mostly about an inch in diameter, but occasionally are of larger size.

Another occurrence of considerable interest is that known as the Round Mount. This is, as the name implies, a small, round hill, possessing a capping of basalt from 10 to 20 feet in thickness, and a series of river-gravels about 25 feet in depth. These gravels are isolated, and their position has given rise to much speculation. There is a ridge of granite separating them from the deposits at the Deep Shaft and the Streak of Luck. The internal evidence, as deduced from the slope of the bottom of the gravels from the edge to the centre of the channel, and also from the arrangement of the pebbles, indicates that the direction of the stream was from west to east at this point. On the northern side, and at a distance of about 100 yards, is another patch of river-gravels, also capped by basalt. The basalt is continuous between the two outcrops of gravel. At this place, the direction of the stream is to the south-east. The wash consists chiefly of quartz-pebbles from 4 mm. up to 4 cm. in diameter, with tourmaline, topaz, and garnet. A number of bluish boulders, from 2 cm. up to 20 cm. in length, resembling those of Soldier Hill, are also present. The isolated position of the Round Mount, and the fact that its river-gravels are at the same level as those of the Deep Shaft, have rendered the problem of determining the relation of the Round Mount, to the main Tertiary stream, a difficult one. The solution of the problem is to be found from the following facts. The trend of the lead at Soldier Hill is in a southerly direction, and, between this place and the Round Mount, occur the redistributed river-gravels at the football-ground. Again, the small patch of gravels, to the north of the Round Mount, is in the line of these occurrences. Moreover, the level of the gravels, at the Round Mount, is lower than that of the Soldier Hill deposits. It has also been pointed out that another mass of redistributed gravels occurs at the Koh-i-noor Mine, which lies between the Round Mount and the Star of the South Mine. There can, then, be little doubt that the part of the lead, flowing from Oakey Creek, continued through the Round Mount, and joined the main stream at a point between the Deep Shaft, and the Star of the South Mine. The position of the surface-gravels at the Sandy block, just west of the Round Mount, is doubtless due to the presence of a tributary joining the Oakey Creek branch at the Round Mount.

In addition to the occurrences just described, which have now been linked up into a continuous river-system, there are a few isolated patches of gravels which deserve a short description.

The Lone Star is the name given to a mine, which comprises two small basalt-capped hills overlying the granite and slate junction to the north of Cope's Creek. The gravels here underlie the basalt, but are at an elevation of 2,380 feet, which is considerably above that of the Tertiary system previously described. The lead at this point trends in a north-westerly direction. Mining is carried on chiefly for tinstone, but a few diamonds are almost invariably found in each washing. At about three miles to the north-west, another outcrop of gravels was noted; it is probable that these all belong to the same stream-course, and that this was a tributary to the main Copeton lead, which flowed north after crossing the present position of Cope's Creek. The general fall of the country was in this direction, as the Tertiary lead at Inverell is at an elevation of about 1,700 feet, and the level at Gragin, still further to the north-west, is about 1,400 feet.

Another isolated area of diamond-bearing gravels, is that situated at Staggy Creek, about 7 or 8 miles to the north-west of the Oakey Creek occurrence. The gravels are exposed at the surface, and no basalt is present. The deposit consists, for the greater part, of quartz-pebbles and boulders, ranging from 5 mm. to 20 cm. in diameter. A relatively large amount of tourmaline is present, and many of the larger quartz-boulders contain pencil-tourmaline. Topaz and jasper are also to be found, and garnet is invariably present where the gravels are diamond-bearing. An iron-band, similar to that at Kirk's Hill and the Banca, was also noted. The whole diamond-bearing area is some 300 yards in length, and rather less than 100 yards in breadth. Its general direction is south-west. The gravels rest on a granite-surface, except at a spot near the centre of the area. Here, a small dolerite-neck, which is 60 yards long, by 10 to 15 yards wide, outcrops at the surface. The diamonds recovered were largest and most abundant in the vicinity of this neck. There are two shafts in the neck; and the dolerite has been examined, but no diamonds have been found in it. The deepest is 70 feet in depth, and the other is 30 feet deep. The dolerite was soft and decomposed for a considerable depth, but was hard and fairly fresh at the bottom of the deep shaft. Gold was found in washing for the diamonds, but only large flakes were recovered, as the method of diamond-washing could not save pieces less than 1·5 mm. in largest diameter. About 10,000 carats of diamonds are reported to have been won from this locality.

v. Geology.

The geological features of the district include

(1) A series of clay-slates.
(2) A series of granites.
(3) Several basalt-flows.
(4) A number of basic dykes.

The clay-slates are the oldest rocks in this area. These have been mentioned in a former paper(3) on the district, and are not important from the point of view of this publication. The granites have been classified, in the same paper, into three types, the Acid granite, the Tingha granite, and the Oakey Creek granite. The granite which occurs at Copeton itself is intermediate in character to the first and second types, and was included, in the paper quoted, with the Tingha granite. A closer examination, however, has indicated that it is perhaps better classed with the Acid type. It is intermediate in chemical composition to the above types, resembling the Acid type more in chemical composition, and the Tingha type in physical characters.

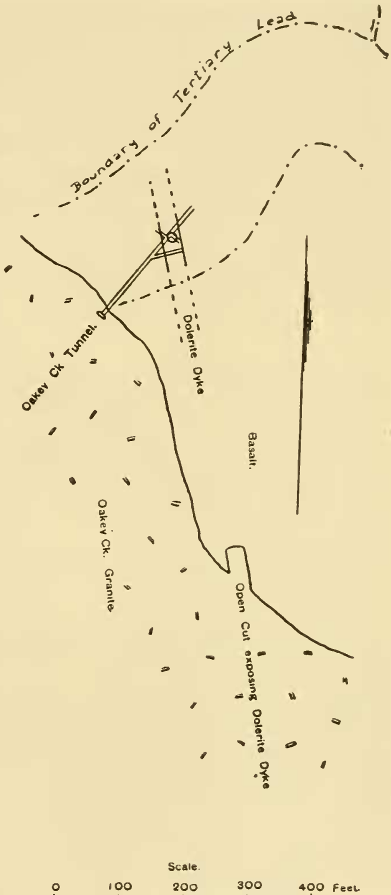
The Acid granite has been shown to be intimately associated with the tin-deposits of the New England plateau. It is a coarse-grained granite, containing quartz-grains from 2 to 5 mm. in diameter, and tabular crystals of pink orthoclase up to as much as 15 cm. in length. A small amount of biotite is usually present, and the rock is not infrequently tourmaline-bearing. It thus has close affinities with the Alaskite of Spurr. The whole Tertiary system of diamond-bearing gravels at Copeton has this rock as its channel-base, with the exception of that part between the Oakey Creek and the Malacca mines, which rests upon the Oakey Creek granite. It is worthy of note that the portions of the Copeton leads which are diamond-bearing are nowhere far distant from the junction of the Acid granite with some other formation, of a greater geological age.

The Tingha granite has been shown to be older than the Acid granite. It is a hornblende-biotite type, containing tabular phenocrysts of plagioclase-felspar. It occurs only at the south-east portion of the area now under consideration. Text-fig. 3 shows the relationships of the series of rocks from Staggy Creek to Rider's Lead.

The Oakey Creek granite has been further investigated since it was last described, and has been found unique in the nature of its inclusions. The granite itself is very coarse, containing phenocrysts of plagioclase up to three inches in length. It is intersected by numerous tourmaline-bearing veins, in which this mineral occurs in long pencils up to three inches in length. The most striking feature, however, is the presence of a great number of inclusions. These are uniformly of one type, and consist of masses of dark-coloured rock containing phenocrysts of felspar similar to those in the granite. The inclusions are frequently more than a foot in diameter, and range in size down to small masses only an inch across. The shape of these is very variable. Some are spherical, others ellipsoidal, while others, again, are subangular. In all cases, the contact of these bodies with the granite is fairly sharp and well defined. The inclusions possess a dark base, consisting chiefly of biotite and quartz, in which are set phenocrysts of felspar and quartz. The felspars normally show signs of corrosion, and may be subangular or even ellipsoidal. A large inclusion, showing corroded felspars, is represented in Plate xc., fig.1.

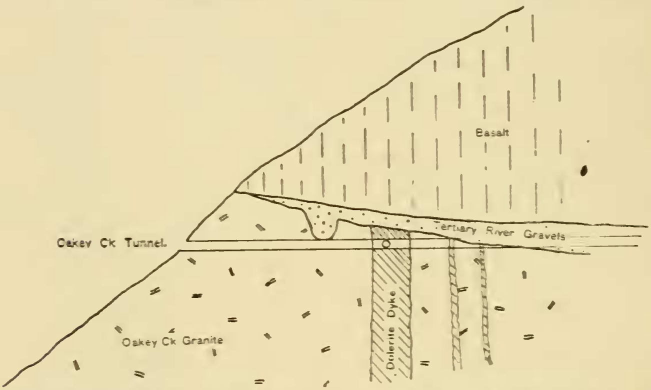
It is of interest to note that inclusions of an identical nature exist in the Acid granite at the Dutchman tin-lode, near Torington. This is about 70 miles to the north-east of the Copeton occurrence. As no such inclusions have been found in the Tingha granite, it is probable that the Oakey Creek granite is more closely related to the Acid granite than to this more basic type. As its morphological affinities, however, are more related to those of the Tingha granite, it is probably intermediate to these two types.

Dykes.—A number of felsite-dykes occur in the Copeton area, and these intersect both the Oakey Creek and Acid granites. None of these have yet been proved to be diamond-bearing, but some of them occur in positions which suggest that they may, at least, be regarded as possible sources of diamond-supply. In addition to these, there are two intrusions of dolerite known in the Oakey Creek granite, and both of these are undoubtedly intimately asso-



Text-fig.4.—Plan of the dolerite-dyke at Oakey Creek showing the spot (marked by a circle) where the diamond was found in matrix.

ciated with diamond-bearing gravels. These have been mentioned in connection with the Tertiary deposits at Oakey and Staggy Creeks. A petrological description of the rocks, and an analysis from each locality, are given under the section on Petrology. It is evident that the rocks are very similar in chemical and physical characters. The analyses show that they differ considerably, in chemical composition, from the peridotite of the South African mines. The Oakey Creek occurrence (Plate xci., fig. 1) deserves special mention. The plan (Text-fig. 4) illustrates the position



Text-fig. 5.—Section illustrating the dolerite-dyke at Oakey Creek.

and known extent of the dolerite-mass at Oakey Creek. The section (Text-fig. 5) shows the relationships of the dyke, granite, river-gravels, and basalt. The linear development and the plane slickensided wall, showing in one of the drives, enable the mass to be classed as a dyke. It is 26 feet wide in the main drive, and is a considerable width at a distance of 500 feet to the south of this drive. The width here cannot yet be determined, as the open cut has disclosed only one boundary of the dyke-mass. There is very clear evidence that this dyke was older than the river gravels overlying it, as an exposure in the easterly drive shows the contact of these. Moreover, decomposed boulders of the dyke-mass are abundant in the river-gravels.

The dyke intrudes the Oakey Creek granite, and the junction is sharp and well defined. Though there is no marginal differentiation in the dolerite, it is common to find in it fragments of quartz, which have undoubtedly been derived from the granite. The microscopic examination reveals the presence of a very small amount of free quartz, but this appears to have crystallised from solution, and not to be of an included nature.

The small neck at Staggy Creek, is composed of practically the same rock. As the localities are distant about four miles, it is probable that the magma, from which the rocks were formed, was of some considerable extent. This neck also intrudes the granite-mass, and no sedimentary rocks occur within some 4 or 5 miles of either occurrence. It must be noted that, in each case, diamond-bearing river-gravels of later age have been found overlying the dolerite-masses.

Not only is this so, but, in the case of one of these, it has been amply demonstrated that a diamond was found fast embedded in the dolerite-matrix. The specimen has been preserved, and has been shown to many eminent geologists by Prof. T. W. E. David, who writes* as follows :—"At the meeting of the British Association at York, England, as well as that of the International Geological Congress of Mexico last September, this specimen was most critically examined by the chief scientific authorities on diamonds in the world, and all were satisfied as to the absolute genuineness of the discovery, and considered it of the highest possible scientific interest." A second diamond was also exhibited with the one embedded in matrix. This was stated to have been found free in the heap of decomposed dolerite. It was agreed, by scientific observers, that this was even better evidence of the genuineness of the discovery, from the fact that the diamond was pitted, and that the pits were filled with finely crystallised dolerite, evidently *in situ*.

Having examined both the above-mentioned specimens, and the spot where they were found, I also feel quite convinced of the genuineness of the discovery.

Active interest was aroused in 1912, and about 100 tons of the dolerite were mined and exposed to the weather. Shortly

* Prof. T. W. E. David, Sydney Morning Herald, 19th and 26th January, 1907.

before my visit, in January, 1913, some nine tons of this were screened and washed. Two diamonds were shown to me, which were reported to have been recovered from this test. About three tons more were washed in my presence, but no diamonds were recovered.

It thus appears that, quite apart from the fact that diamonds have been found in the dolerite, the evidence points to the dykes as the probable source of the diamond-supply. From the great variety, both in size and character, of the diamonds from different parts of the leads, it is probable that the diamonds have been derived from a great number of such dykes or necks. These are, probably, like the Oakey Creek occurrence, still hidden by the recent basalt-flows.

vi. Petrology.

The Oakey Creek Granite.

Crystallinity: holocrystalline.

Grainsize: *relative*, porphyritic; *absolute*, smaller crystals from 3 to 6 mm.; phenocrysts up to 8 cm.

Fabric granitoid; also graphic intergrowth of quartz and orthoclase in some instances.

Minerals in order of decreasing abundance: quartz, orthoclase, albite, biotite, microcline, muscovite, magnetite, apatite, and fluorite.

Secondary minerals: kaolin and chlorite.

The felspars have crystallised out in two generations; the older ones are idiomorphic, zoned, and fairly free from decomposition, while the opposite characteristics mark the later felspars. These remarks apply to both the orthoclase and the albite. The biotite is a dark variety, its pleochroism varying from yellowish-brown to very dark brown.

A small amount of microcline is present in subidiomorphic crystals.

The muscovite is rather rare, and is mostly included in the orthoclase. It oppears to have been corroded by the magma subsequently to its complete crystallisation.

The apatite possesses its characteristic, prismatic habit.

One or two very small allotriomorphic grains of fluorite were observed in one slide of this rock.

Quartz-dolerite. *Loc.*—Oakey Creek.

Crystallinity : holocrystalline.

Grainsize : evengrained, the typical crystals varying from 2 to 6 mm.

Fabric : a network of plagioclase felspars with subordinate augite. The interstitial material is a brown chlorite, with a few decomposed biotite crystals.

The chief minerals, in descending order of abundance, are oligoclase, labradorite, augite, chlorite, magnetite, biotite, and quartz.

A little secondary hornblende is present, and the felspars, though fairly fresh, on the whole, show some signs of kaolinisation along some of the major cleavage-cracks. The felspars vary from oligoclase to basic plagioclase. The most basic felspar-crystals, as determined by the method of Michel Levy, are labradorites of the composition Ab_2An_3. Many of the crystals are strongly zoned, and the different zones vary widely in composition. The outer edge is often oligoclase, and the central area anorthite. The augite, which is very fresh, is an almost colourless variety, with a faint colour suggesting that it is titanium-bearing. It is intermediate in composition between diopside and true augite.

The most interesting, and, at the same time, most puzzling feature, is the presence of the brown, chloritic, interstitial material, and also idiomorphic quartz-crystals The chlorite is often arranged in a manner which suggests that it has been derived from an augite, which was originally involved in an ophitic structure with the plagioclase. The structure has been variously interpreted by different observers. Professor Bonney and Professor David have suggested that the chlorite is a secondary product derived from a primary hornblende. Dr. A. Thompson has considered its derivation from augite unlikely, because of the freshness of the augite associated with the felspar in the rock. He has suggested that the chlorite may represent a devitrified glass.

There is, however, a constant association of idiomorphic quartz-crystals with the chlorite, which has not, so far, been recorded. In Plate xci., fig.3, this arrangement may be seen. The small, clear, hexagonal crystal, in the darker mass surrounding it, is a quartz-crystal in chlorite. This structure occurs only on a small scale, but it is very characteristic of the whole rock. In places, the quartz has been partly resorbed, and the chlorite-fibres penetrate into it. Again, it is not uncommon to find a modified graphic intergrowth of chlorite and quartz. From this, it would seem that the quartz crystallised rather before the chlorite, on the whole, but that, in certain parts, the crystallisation was simultaneous.

These relations of the quartz and chlorite seem opposed to the derivation of these minerals from a primary mineral, such as hornblende or augite, or even from a glassy base. On the other hand, much of the magnetite and ilmenite appears to be of a secondary nature. The opaque crystals are, in places, moulded about the felspars and the augite. A considerable amount of the iron-ores appears to be associated with the chloritic material.

A number of acicular crystals are present, which are idiomorphic to the felspar. These appear to be tremolite. They do not appear to bear any definite relation to the chloritic material.

Leucoxene is present, bordering the ilmenite.

Quartz-dolerite. *Loc.*—Staggy Creek.

Crystallinity: holocrystalline.

Grainsize: relatively evengrained, the normal crystals varying from 2 to 5 mm. in diameter.

Fabric: a network of plagioclase felspars, with grains of nearly colourless augite. The augite is very subordinate in amount, being distinctly less abundant than in the Oakey Creek dolerite. There also occurs a considerable amount of interstitial chlorite, as in the Oakey Creek dolerite.

The chief minerals, in descending order of abundance, are oligoclase, labradorite, augite, chlorite, ilmenite, magnetite, quartz, and biotite.

The felspars are very similar to those of the Oakey Creek dolerite, but the sample was not so fresh in this rock, and the felspars, consequently, are more kaolinised. The most basic felspar observed was labradorite of the composition Ab_3An_7, and, the most acid, an albite-oligoclase. Zoning occurs in the felspars, the composition of the zones varying from albite-oligoclase at the margin, to basic plagioclase in the centre of the crystals.

The augite, which is slightly more coloured than that of the Oakey Creek dolerite, is much less abundant than in that rock. The grains, moreover, are much smaller in size.

The chlorite, which is also less abundant than in the Oakey Creek dolerite, has the same characteristic relation to the felspars, and, moreover, the same strange property of including idiomorphic quartz-crystals. These quartz-crystals are, however, less abundant in this rock. The same problem as to the origin of the chlorite, therefore, exists.

Ilmenite is more abundant than in the Oakey Creek dolerite, as also is leucoxene.

Analyses and Molecular Ratios.

i. Oakey Creek quartz-dolerite.
ii. Staggy Creek quartz-dolerite.
iii. Hard rock (blue ground) De Beer's Mine, Kimberley.
iA. Molecular ratios of i.
iiA. Molecular ratios of ii.

	i.	ii.	iii.	iA.	iiA.
SiO_2	50·43	51·16	49·50	841	853
Al_2O_3	14·72	17·98	18·40	144	176
Fe_2O_3	2·90	2·85	13·10 (Fe₂O₃ + FeO)	18	18
FeO	4·59	4·09		64	57
MgO	6·67	4·10	5·25	167	102
CaO	7·13	7·30	2·24	128	130
Na_2O	2·47	3·92	4·65	40	63
K_2O	1·23	1·61	1·48	13	17
H_2O-	3·49	2·51	5·23 (H_2O-, H_2O+, CO_2)	193	139
H_2O+	3·82	2·32		212	129
CO_2	1·67	1·03		38	23
TiO_2	0·82	1·27	—	10	16
P_2O_5	0·22	none	—	1	none
MnO	0·03	—	—	—	—
Cr_2O_3	0·02	—	—	—	—
V_2O_5	0·03	—	—	—	—
SO_3	0·01	—	—	—	—
	100·25	100·14	99·85	—	—

Norm of the Oakey Creek quartz-dolerite.

Quartz	9·36
Orthoclase	7·21
Albite	20·96
Anorthite	24·20
Hypersthene	20·14
Calcite	3·80
Corundum	0·30
Magnetite	4·18
Apatite	0·31
Ilmenite	1·52
Water	7·31
	99·29

Norm of the Staggy Creek quartz-dolerite.

Quartz	2·70
Orthoclase	9·62
Albite	33·01
Anorthite	26·69
Diopside	14·52
Magnetite	4·16
Ilmenite	2·44
Calcite	2·30
Water	4·83
	100·27

Both the microscopical examination and the analyses of the Oakey Creek and Staggy Creek rocks indicate their close relationship. The association of each of them with diamonds in Tertiary river-gravels is another harmonic relation. In view of the evidence for the occurrence of diamonds in the Oakey Creek dolerite, there can be little doubt that the Staggy Creek rock is also diamond-bearing.

The diamonds in South Africa seem to be found associated with a more basic rock—a peridotite in which the silica-percentage is often below 40 %, and the percentage of magnesia above 25 %. There cannot, therefore, be said to be a close relationship between the South African peridotites and the Copeton dolerites.

It is interesting to note, however, that rocks very similar to the Copeton dolerites have been found in the peridotite-necks of South Africa.

Analysis numbered iii., is of a "hard rock" from the blue ground of De Beer's mine at Kimberley. This rock closely resembles the Staggy Creek dolerite, the chief difference being that the South African rock possesses about 6 % more of the iron oxides, and about 5 % less lime than the New South Wales variety.

In addition to this rock, I have examined microscopically an olivine-dolerite stated to be from the Kimberley pipe, which, apart from its relatively small percentage of olivine and absence of quartz, is not unlike the Oakey Creek dolerite.

Although these two South African rocks do not appear to represent the type-rocks of the South African diamond-bearing necks, it is interesting to note that they do occur associated with the diamond-deposits.

vii. Summary.

The first discovery of diamonds in the Copeton district was made in 1872 or 1873, simultaneously with the discovery of tinstone in the district. The diamonds were first found in alluvial workings, but these had been derived from the denudation of basalt-capped leads. These leads are probably of late Tertiary age. The physiographic investigation shows that the present drainage-system of the district trends to the west, but the prebasaltic drainage was in a northerly direction. The original course of the Gwydir was northwards from Copeton to Inverell, and it then received the Macintyre as a tributary stream. The present course of the Gwydir has followed the eastern and northern edges of a block-fault. The western boundary of this block-fault has been examined by W. N. Benson, and we have agreed to name the sunken area "Keera," from a Station of that name situated in the area of subsidence. The basalts and river-gravels (which are after Anderson) shown on the accompanying map, illustrate the Tertiary river-system in its relation to the present-day drainage.

The material filling the beds of the Tertiary stream-channels is grouped under four heads: (1) the wash; (2) the drifts; (3) clay-deposits; (4) lignite. There is no locality in which all four are developed, and, as a rule, only the first two are present. The wash is the term applied to the coarser bands of material. This has usually collected on the base of the stream-channel, and contains the heavier minerals. Consequently, it is essentially the diamond-bearing stratum of the deposit. The wash seldom exceeds one foot in thickness. The drifts are aggregates of loose and rather fine, sandy material, usually stained red from the leaching of iron oxide from the overlying basalt. These deposits attain, in several places, a thickness of 20-25 feet. The clay-deposits consist of kaolin derived from the decomposition of the felspars in the granite, and have been deposited under lacustrine conditions. Lignite occurs rarely, and overlies the drifts. It does not appear to have been much affected by the overlying basalt.

The geology of the district is represented on the accompanying map. It will be seen that there are present (1) slates; (2) granite; (3) dykes; (4) basalt.

The slates cover a small area, and are unimportant in connection with this paper. The granite is represented by three types —the Acid, Tingha, and Oakey Creek granites. The first is the younger, and the last is probably intermediate in age to the first two types. The dykes are of two varieties—(*a*) fine-grained felsites; (*b*) dolerites. These dykes have intruded the granites, but are older than the basalts and the basalt-capped leads.

The basalts are the youngest rocks in the district. These overlie the Tertiary gravels, and obviously cannot have been a source of diamond-supply. It is also shown that it is highly improbable that the diamonds can have been derived from either the slate or the granites. This points to the dykes as the probable origin of the diamond-supply.

This "proof by exhaustion" evidence in favour of the dyke-material as the diamond-matrix has been confirmed by the discovery of a diamond in the dolerite-dyke at Oakey Creek. A Tertiary stream-channel has crossed this dyke, and diamonds were found in the gravels adjacent to the dyke on the downstream side of it. A similar dyke, or small neck, of an almost identical rock was found at Staggy Creek, some 4 miles northwest of this occurrence. In this case, also, diamonds were found in the gravels overlying the dolerite-mass. The occurrence of two such masses of dolerite, associated with the diamond in this area, gives strong grounds for supposing that the whole of the diamonds of the Copeton field have been derived from similar sources. The two known dolerite-masses are so situated that they cannot have supplied more than a portion of the Tertiary deposits.

It is probable that most of the sources of supply of the diamonds are now concealed by the later basalt-flows, in the same way as the Oakey Creek occurrence.

In conclusion, I take the opportunity of here thanking those who have assisted me in this work. To the miners of Copeton, and pre-eminently to Mr. A. R. Pike, my best thanks are due for kind assistance in field-work. I am also indebted to Professor David, for help and encouragement during the preparation of this paper; and to Mr. A. Pain, for some assistance in rock-analysis.

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EXPLANATION OF PLATES XC.-XCII.

Plate xc.

Fig.1.—Inclusion in the Oakey Creek granite, near its junction with Cope's Creek, showing large phenocrysts of felspar set in a ground-mass of felspar and biotite.

Fig.2.—View of Copeton from Soldier Hill, looking east. The foot-hills in the distance mark the trend of the Tertiary lead from the Deep Shaft to the Old Farm.

Plate xci.

Fig.1.—Oakey Creek, showing the mouth of the tunnel in which a diamond was found in the matrix.

Fig.2.—The bed of Cope's Creek, near its junction with the Gwydir, showing remarkable triangular depressions left after a small flood.

Fig.3.—The Oakey Creek dolerite, showing felspars, augite, ilmenite, and chlorite. Note the small hexagonal section of quartz embedded in chlorite.

Plate xcii.

Geological Map showing the Tertiary Leads of the Copeton Diamond-field.